Moisture Nonuniformity and Sampling Errors in Large Cheddar Cheese Blocks

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A study was made of the impact of nonuniform moisture distribution in 290 kg blocks of cheese on the accuracy of sampling the cheese for moisture content. The range of moisture from center to outside surfaces of the blocks was about 5%. The temperature gradient, developed in the first 24–48 h after cheese making, drove the moisture migration from warm to cold areas in the cheese blocks during initial cooling. The moisture gradient from center to outside of each block, the non-symmetrical nature of the gradient, and the actual length of the core sample all contributed to random and systemic error in sampling within a single cheese plant. It was concluded that average moisture differences from vat to vat in a factory were small, and large variations in moisture tests were due to sampling errors.

In the United States, Cheddar cheese has been traditionally produced in 18 kg (40 lb) blocks. In a highly cost-competitive market, more automated and efficient means of handling large quantities of cheese in rapidly expanding cheese factories were developed to control cost. In the late 1970s and early 1980s, the first 290 kg (640 lb) block Cheddar production lines were used. One 290 kg block replaced sixteen 18 kg blocks. The approximate dimensions of a 290 kg block are 71.1 cm tall × 55.9 cm wide × 71.1 cm long (Figure 1). The 290 kg block system reduced labor and handling costs (1), on-the-job lifting injuries, intermediate packaging costs (1), and trim loss when blocks were converted to exact weight pieces for the retail market. Although the handling of 290 kg blocks with forklifts was efficient and easy, the cooling of Cheddar cheese in these large blocks immediately after manufacture was more difficult.

As the 290 kg block systems became common in the industry, it was apparent that there was systematic variation in composition and cheese quality within 290 kg blocks. The first information on this problem was collected within large cheese manufacturing companies and is not available in the literature. In 1988, Reinbold et al. (2) observed that after 7 days moisture had traveled from areas of high to low temperature in 290 kg stirred-curd, full-fat Cheddar blocks, and curd had not completely fused and was still porous after 24 h of cooling. In another report, Reinbold et al. (3) described systematic variation within 290 kg blocks. At the start of cooling, moisture was high in the center of the block (41.82%) and low at the outside (37.48%). A temperature gradient developed from the exterior (15°C) to the interior (35°C) within 24 h. It took 12 days for the interior to reach 2°C. After only 24 h, a moisture and pH gradient within the block was established that was the reverse of that found immediately prior to cooling. The exterior was 38% moisture, and pH, 5.2 whereas the interior was 35% moisture, pH 5.1. They concluded that moisture moved in response to temperature and pH gradients. They hypothesized that shrinkage of casein micelles in the center and swelling of micelles at the outer areas of the 290 kg blocks, resulting from the temperature difference from the center to the outside during cooling, may have provided a driving force for the outward moisture transfer. Temperature was the variable that had the largest effect on moisture.

In 1992, Reinbold et al. (4) determined the effect of 290 kg block container materials on the development of temperature gradients and total time of block cooling. It took 12 days for the center to cool from 32 to 2°C in stainless steel and 14.75 days in plywood forms. Thus, the type of exterior material for the 290 kg form will influence cooling rate, but in general the cooling time is 10 days or longer in all types of materials used. Immediately after filling and before cooling, 290 kg blocks of Cheddar cheese are given various vacuum and pressure treatments. In some cases, perforated stainless steel probes are inserted into the cheese curd immediately after the 290 kg blocks are filled, and a vacuum is applied to help remove “free” whey from various locations within the block. Next, 290 kg blocks may be pressed for some period of time before they enter a vacuum/pressing chamber designed to close the structure of the curd within the block. Reinbold et al. (5) measured the influence of pressing or not pressing the curd prior to vacuum treatment. They concluded that too much pressing before vacuum treatment may compress the curd at the exterior surface of the block to produce a barrier to air and whey evacuation and may produce mechanical openness in the interior of the cheese. They reported that excessive free moisture trapped in the blocks at the start of cooling might increase uneven moisture distribution in cheese. However, they found that the various pressure treatments had no significant impact on the formation of a moisture gradient from the center of the block to the outside during cooling.
Although extensive work has been focused on the issue of moisture variation within 290 kg blocks, the problem has not been resolved. A key point is that the magnitude of the difference in moisture within 290 kg blocks gets larger as the fat content of Cheddar cheese is reduced and the moisture content is increased. Thus, at a time when the industry was trying to develop and offer the consumer improved low-fat Cheddar cheese products, the problem of nonuniform moisture content within the blocks got worse. This increased consumer complaints and also increased trim loss on these products during cutting for exact weight retail pieces. In 50% fat-reduced Cheddar, the moisture gradient that forms within a 290 kg block can be as large as 6% from the center to the outside. The cheese in the center of the block is hard and dry, while the cheese near the outside of the block is excessively soft. The moisture gradient can be as large as 7–9% in fat-free Cheddar varieties. In addition to the obvious quality problems that this situation creates, it also becomes a major sampling problem for quality control laboratories.

The objective of this research was to characterize the impact of nonuniform moisture distribution in 290 kg blocks of

Figure 1. Dimensions and sampling locations within 290 kg cheese blocks.
Figure 2. Cross section of mean moisture profile of direct-filled 290 kg block of Cheddar cheese at 35.56 cm from front (middle) of block. Mean of 4 blocks.

Figure 3. Cross section of mean moisture profile of direct-filled 290 kg block of Cheddar cheese at 25.4 cm from front of block. Mean of 4 blocks.
Figure 4. Cross section of mean moisture profile of 290 kg block of Cheddar cheese assembled from sixteen 18 kg blocks of Cheddar cheese at 35.56 cm from front (middle) of block. Mean of 4 blocks.

Figure 5. Cross section of mean moisture profile of 290 kg block of Cheddar cheese assembled from sixteen 18 kg blocks of Cheddar cheese at 25.4 cm from front of block. Mean of 4 blocks.
cheese on accuracy of sampling the cheese for moisture determination.

**Experimental**

A cheese making experiment was conducted in a commercial cheese factory. Fifty percent fat-reduced Cheddar cheese was produced by a stirred-curd manufacturing process. The 290 kg boxes (plywood forms) were filled with stirred curd at ca 25°C, and free whey was removed with press probes after filling. The blocks were pressed without vacuum for ca 30 min, and then pressed with vacuum. Whey normally comes out of the blocks at the probe station, in the vacuum press, and in the cooler during the first 24 h of cooling. After vacuum pressing, the 290 kg boxes were closed and moved to the cooler. Four blocks of cheese were selected. Each block was made from a different vat of cheese. Two of the blocks were made on one day and 2 were made on the next day. At the same time, additional stirred curd from each of these same vats of cheese was packed directly into 16 traditional 18 kg blocks and pressed for 1 h in an A-frame press. The sixteen 18 kg blocks were removed from the A-frame press, and the pressed 18 kg blocks of cheese were removed from their individual forms and placed into a 290 kg form. Each of these assembled 290 kg blocks of cheese went through the vacuum pressing with its sister block that had been filled directly with curd. The purpose was to determine if pre-pressing the curd into 18 kg blocks to allow faster and more complete whey drainage, and then collating them, would prevent the later migration of moisture within the block. After 90 days of aging at 4°C, the eight 290 kg blocks of cheese were taken to a cutting facility for sampling that was designed to characterize moisture distribution within each block. The sampling system was developed in preliminary experiments (data not shown) by taking 40 samples from each block, using 290 kg blocks from the same factory.

In the final sampling scheme developed for this experiment, 32 samples were taken for moisture analysis from each of the eight 290 kg blocks (4 direct filled and 4 collated). The dimensions of a 290 kg block of cheese are 71.1 cm long × 71.1 cm high × 55.9 cm wide for full-fat Cheddar cheese. The sampling pattern used in this study is shown in Figure 1. Samples 1–9 were taken from within the top plane of the block, samples 10–18 were taken from a plane half way between the top and bottom of the block, and samples 19–27 represented the same locations at the bottom of the block (Figure 1). To characterize moisture variation more completely in the vertical direction within the block from the center to the outside, samples 5, 28, 14, 29, and 23 represent a vertical column of cheese at the center of the block; samples 30–34 represent a vertical column of cheese half way between the center and an outside corner; and samples 1, 35, 10, 36, and 19 represent a vertical column of cheese in the corner of the block (Figure 1). Each rectangular sample piece was ca 14 × 4.1 × 4.1 cm.
of the 36 complete sample pieces was ground in a Waring blender. Two grams of cheese sample were weighed into an aluminum weighing dish and samples were dried for 24 h at 100°C. The oven specifications and analysis conditions were as described in AOAC Method 990.20 (6). Each cheese sample was analyzed in duplicate.

Results

Moisture Variation within Block

The range of moisture from center to outside surfaces of the 290 kg blocks was approximately 5%. Figure 2 shows the average moisture variation within the block as a cross section taken vertically at the middle (35.56 cm from front and back) of the 4 blocks filled directly with cheese curd. The variation is shown as concentric egg-shaped zones of increasing moisture content from center to outside of the block. The wide end of the egg shape is oriented toward the bottom surface of the block during draining and pressing. The center zone (Figure 2) contained 42.3% moisture. In Figure 3, the moisture profile is shown at 25.4 cm from the front face of the block. In this cross section the size of the lowest moisture zone in the center of the block is smaller, because it is moving away from the center of the zone. At a depth of 20.3 cm into the block, this zone would no longer be visible because the cross section would no longer transect the driest 3 dimensional egg-shaped zone in the middle of the block. A similar analysis was made of direct filled 290 kg blocks produced in another factory (data not shown). The pattern of moisture distribution was similar, but the egg-shaped pattern was inverted compared to that in the first factory. This was caused by an extra inversion of the blocks after they came out of the vacuum press and before they went into the cooler.

In contrast to the direct-filled blocks, the assembled 290 kg blocks did not express any whey (lose weight) during the vacuum pressing or in the cooler during the first 24 h. However, the moisture range in the assembled 290 kg blocks was almost as large as the direct-filled 640 blocks (4.5 vs 5%). Thus, the temperature gradient during cooling of the assembled 290 kg blocks induced moisture migration within the block even though no moisture was draining from the block. Figure 4 shows the moisture gradient for the assembled blocks at a cross section depth of 35.56 cm. The center zone in Figure 4 contained from 42.8 to 43.2% moisture. The moisture variation was more symmetrical (oval instead of egg-shaped) than for the direct-filled 290 kg blocks in Figures 2 and 3 because most of the whey had been removed from the 18 kg blocks during the 1 h pressing in the A-frame press before they were inserted into a 290 kg form. Also, the position of the central dry zone is more symmetrically placed from top to bottom within the block. At 25.4 cm depth, the dry central portion is still visible (Figure 5).

Therefore, consistent with other published reports, we conclude that the temperature gradient developed during the early stages of cooling is the factor that drives the moisture migration from warm to cold areas within 290 kg blocks of Cheddar cheese during the initial cooling. This gradient was developed in the first 24–48 h after cheese making. The moisture nonuniformity changes very little with time of aging.

Dimensions of the Block and Placement of Sampling Holes

How does nonuniformity in moisture distribution influence sampling? When Cheddar cheese is packed in 290 kg blocks, there are holes in the forms (which are either wood, metal, or plastic) where a stainless steel cheese trier is inserted for sampling. The trier is inserted into the block to remove a 35.56 cm long core sample. There are two sampling holes in the face of the narrow sides (55.88 cm) of the 290 kg form. The lower sampling hole is centered up from the bottom of the block at 28.75 cm up and 20.95 cm to the right of the left side. The upper sampling hole is centered 47.63 cm above the bottom of the block and 20.95 cm to the left of the right side of the block.

Sampling Error

The moisture gradient from the center to the outside of each block, the non-symmetrical nature of the gradient, and the actual length of the core sample removed with the cheese trier all contribute to random and systematic error in sampling within a single cheese plant. If the core breaks off and only the outside area of the cheese within the block is sampled (because of cheese texture), the moisture test on this core will not be representative of the block. It is very difficult for the person taking the sample to do anything about this. Also, if the variation in moisture within the block is not symmetrical, there will be a difference in sample and test between a core of cheese removed from the upper and lower sampling holes in the side of the 290 kg block. The impact of core length and trier hole position are shown in Figure 6. The mean moisture content for the block is shown as a horizontal line at 44.2% moisture. The other 2 lines represent the moisture test that would be obtained with different lengths of cheese core removed by the trier. For example, a core 10.2 cm long would be 10.2 cm from the exterior surface of the block to a position 10.2 cm into the block. The block has higher moisture near the surface as can be seen in Figures 2–5. Thus, the shorter the length of the core sample, the higher the measured moisture content. Also, there will be a systematic bias between the lower and upper sampling holes in the side of the block at all core lengths. Different lengths and different positions (lower or upper) of cores of cheese sample will provide a different moisture value for the block. In this characterization of the within-block variation for this factory, the length of core that would predict the average moisture for the block would be about 11.45 cm for the lower sampling hole and 19.05 cm for the upper sampling hole. The experience in this factory was that the moisture content of the cheese varied extremely from vat to vat within the same day. In addition, there were large variations in estimates of moisture adjusted yields as a percentage of theoretical cheese yield (7). It was concluded that the real average moisture differences from vat to vat in this factory were small and the large variations in moisture tests were due to sampling errors. Research is continuing to find a technological solution to prevent
moisture from moving from the center of the 290 kg cheese blocks to the outside surfaces during cooling.

References

(6) Official Methods of Analysis (1999) 16th Ed., 5th Rev. AOAC INTERNATIONAL, Gaithersburg, MD